EVALUATION OF SATELLITE-BASED OPTICAL AND THERMAL TRAPEZOID METHODS FOR GROUNDWATER TABLE DEPTH MONITORING IN ESTONIAN BOGS

Iuliia Burdun[1], Valentina Sagris[1], Michel Bechtold[2,3], Viacheslav Komisarenko[4], Ülo Mander[1] and Gabrielle De Lannoy[2]

iuliia.burdun@ut.ee

INTRODUCTION

The position of the water table in the peat layer relative to the ground surface, i.e. the water table depth (WTD), is an important feature of peatlands.

We explored the feasibility of applying the satellite based soil moisture indices for the WTD monitoring in two peatlands in Estonia. The specific objectives were to:

- calculate two thermal-based and one shortwave-infrared-based soil moisture indices using Landsat 5, 7 and 8 observations (2009 – 2019),
- evaluate the temporal and spatial correlation of the indices with in-situ measured WTD.

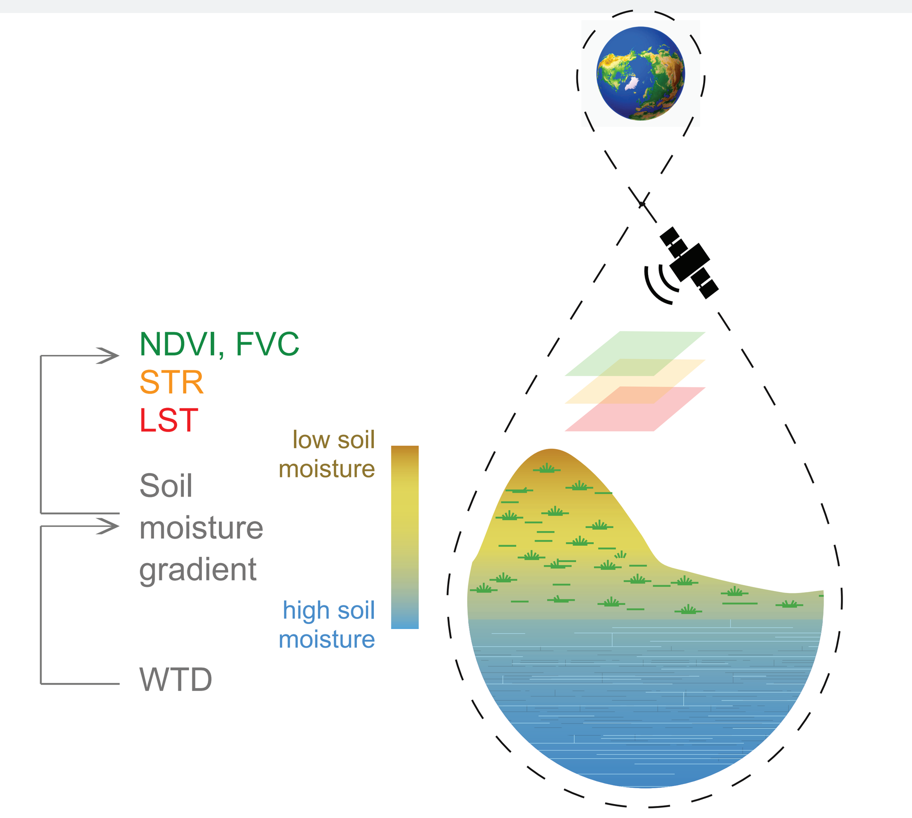

Fig. 1. Sketch illustrating the concept of connection between water table depth (WTD) and remotely sensed parameters via the capillary connection between surface soil moisture and WTD. The concept is presented for the remotely sensed parameters used in this study: normalised difference vegetation index (NDVI), fractional vegetation cover (FVC), land surface temperature (LST) and shortwave infrared transformed reflectance (STR).

MATERIALS AND METHODS

One of the most well-known approaches for soil moisture estimation is the "trapezoid" model concept (Sadeghi *et al.*, 2017). Two different types of the trapezoid concept exist:

Thermal-Optical TRApezoid Model (TOTRAM)

$$W_{TOTRAM,i} = \frac{LST_{max,i} - LST_i}{LST_{max,i} - LST_{min,i}},$$

Optical TRApezoid Model (OPTRAM)

$$W_{OPTRAM,i} = \frac{STR_i - STR_{min,i}}{STR_{max,i} - STR_{min,i}},$$

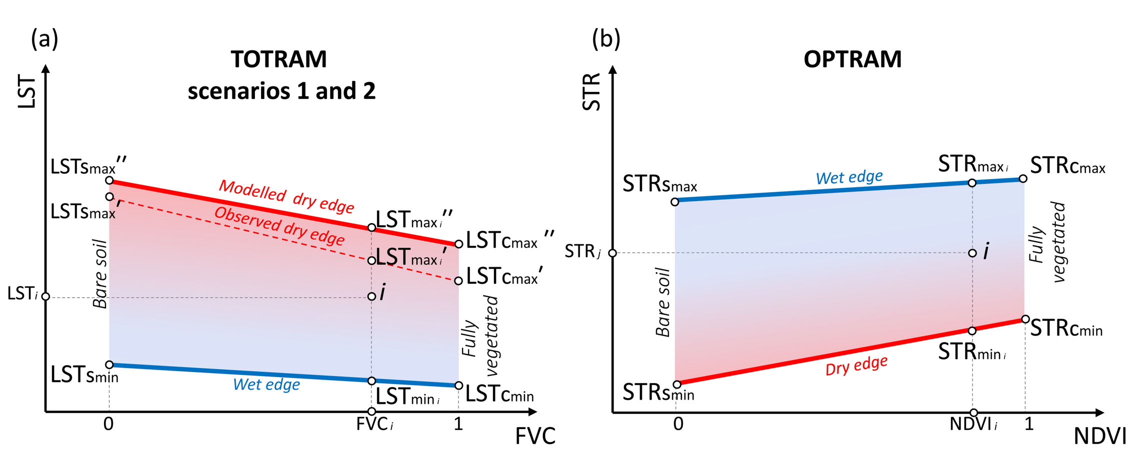

Fig. 2. Illustration of the concept of the (a) TOTRAM and (b) OPTRAM. LST is the land surface temperature, FVC is fractional vegetation cover, NDVI is the normalised difference vegetation index, STR is the shortwave infrared transformed reflectance. For TOTRAM, both the observed (scenario 1) and the modelled (scenario 2) dry edges are presented. The colour gradient shows the soil moisture availability from blue (wet edge) to red (dry edge).

MATERIALS AND METHODS

In TOTRAM scenario 1 the estimation was solely based on observed pixel values. The remotely sensed LST and FVC data were used to construct the trapezoid with its dry and wet edges.

In TOTRAM scenario 2, additionally to LST and FVC, supplementary data were used to model the theoretical dry edge, among which are friction velocity and total column water vapour data from ERA5, land surface albedo and in-situ meteorological data.

The OPTRAM soil moisture index was calculated based on remotely sensed STR and NDVI data.

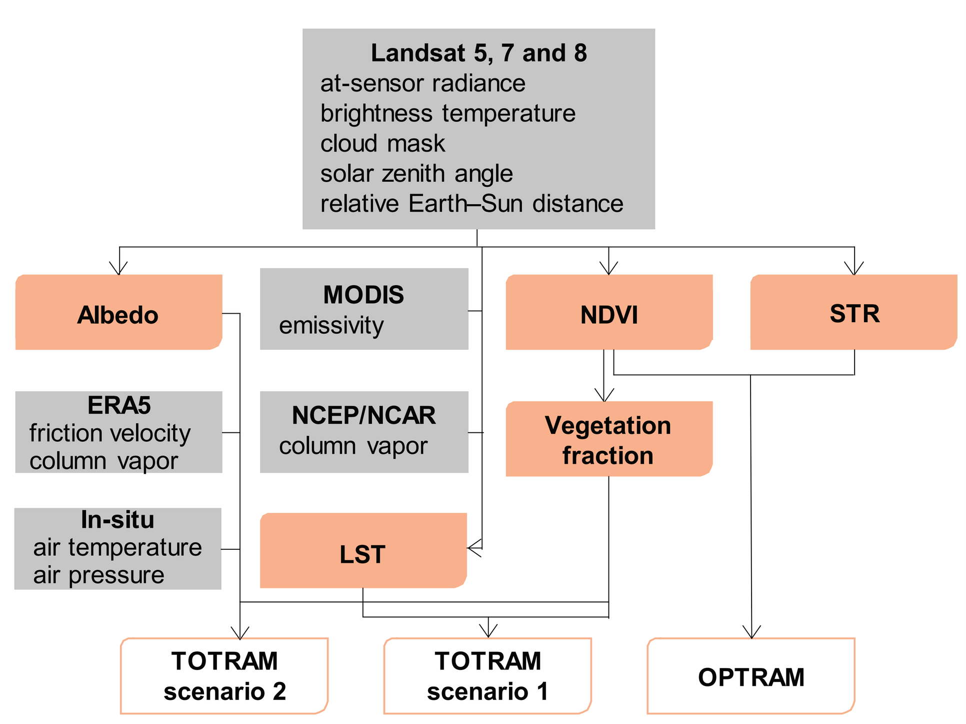

Fig. 3. Flowchart of the data preparation for the two TOTRAM scenarios and OPTRAM. Grey-filled rectangles represent input parameters and variables, orange-filled rectangles with diagonal corners rounded represent intermediate parameters and variables.

RESULTS

TEMPORAL CORRELATION OF SOIL MOISTURE INDICES WITH WTD

Figure 4 shows for each pixel the temporal correlation coefficient R between the mean WTD of the 8 monitoring wells and soil moisture indices. For the two TOTRAM scenarios the R values are close to zero. R values of OPTRAM are positive throughout the whole bog area. The highest R values are observed for treeless areas.

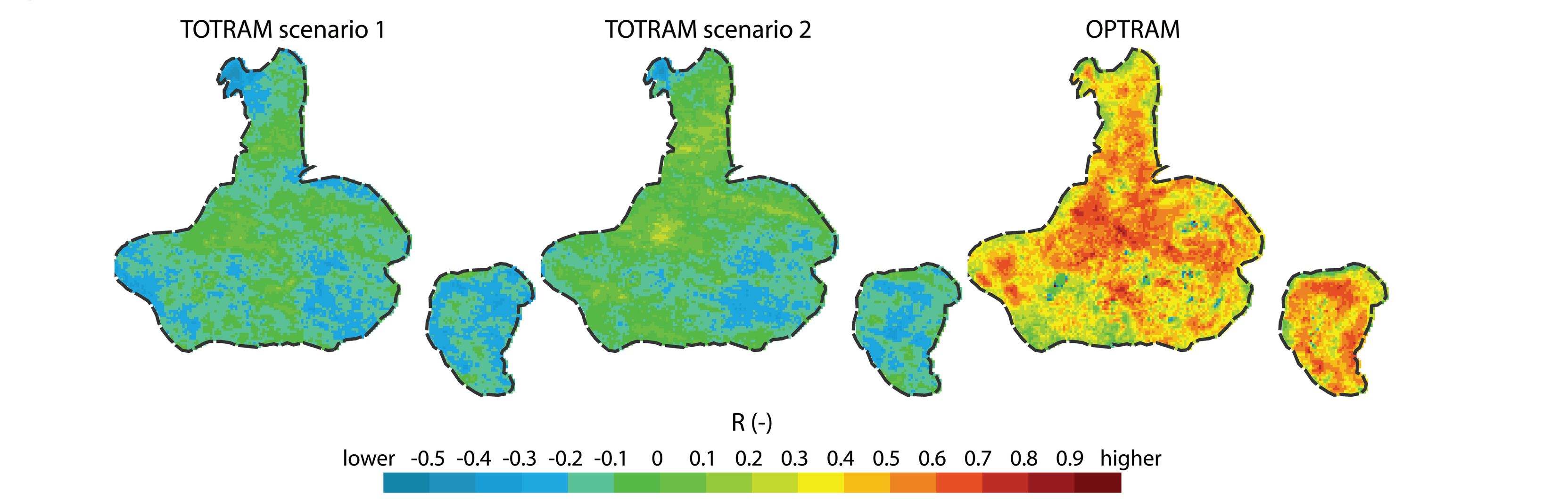

Fig. 4. The long-term per-pixel temporal correlation coefficient (R) estimated for the average water table depth from all the wells and soil moisture indices derived from TOTRAM scenario 1, TOTRAM scenario 2 and OPTRAM.

RESULTS

SPATIAL VARIABILITY OF SOIL MOISTURE INDICES AND WTD

Figure 5a-b indicate that the soil moisture indices from both TOTRAM scenarios do not positively correlate with WTD. Only the OPTRAM indices show a positive correlation over the whole WTD range (Figure 5c). Figure 5c shows that OPTRAM indices over treed parts of the bog are systematically higher than over the treeless parts of the bog.

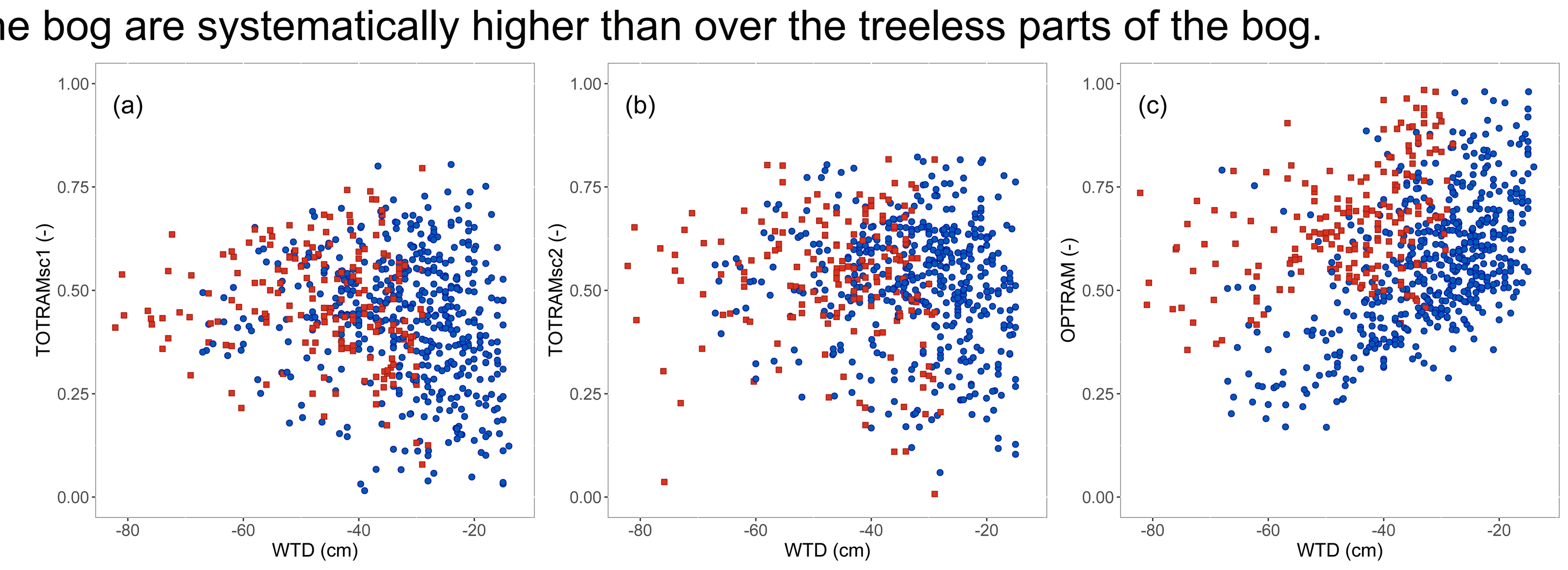

Fig. 5. Soil moisture index from (a) TOTRAM scenario 1, (b) TOTRAM scenario 2, and (c) OPTRAM as a function of water table depth (WTD) measured at 3 sites in treed (red squares) and 5 sites in treeless parts (blue circles) of the bogs.

CONCLUSIONS

We evaluated the temporal and spatial relationships between in-situ measured WTD and soil moisture indices from three different trapezoid models over two northern bogs in Estonia. We compared the performance of two trapezoid models based on optical and thermal imagery (TOTRAM scenario 1 and 2) and one solely based on optical imagery (OPTRAM). Our results demonstrated:

- a general inapplicability of the TOTRAM index for WTD monitoring in our study area,
- a high potential of OPTRAM index for monitoring temporal changes in WTD,
- the highest temporal correlation coefficients (0.8) for the OPTRAM index over treeless bog areas with little or no surface water (no bog pools), and
- a high sensitivity of OPTRAM index to the vegetation type which strongly limits the spatial interpretability and probably also the temporal interpretability under progressive vegetation changes.

1 University of Tartu, Department of Geography, Institute of Ecology & Earth Sciences, 46 Vanemuise St., Tartu, 51014, Estonia
2 KU Leuven, Department of Earth and Environmental Sciences, 3001 Heverlee, Belgium
3 KU Leuven, Department of Computer Science, 3001 Heverlee, Belgium
4 University of Tartu, Institute of Computer Science, Chair of Data Science, 2 J. Liivi St, Tartu, 50409, Estonia